

**APPLICATION**

**FOR**

**UNITED STATES LETTERS PATENT**

**TITLE:**           HERMETICALLY PACKAGING A  
                  MICROELECTROMECHANICAL SWITCH AND  
                  A FILM BULK ACOUSTIC RESONATOR

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Express Mail No. EL 990 136 162 US

Date: February 5, 2004

HERMETICALLY PACKAGING A MICROELECTROMECHANICAL  
SWITCH AND A FILM BULK ACOUSTIC RESONATOR

Background

This invention relates generally to microelectro-mechanical system (MEMS) radio frequency switches and film bulk acoustic resonator filters.

5        In a number of radio frequency applications, a radio frequency MEMS switch and a film bulk acoustic resonator filter are used together. Currently, filter devices, such as film bulk acoustic resonators, are packaged individually. If one desires to utilize a MEMS switch with  
10 such filter devices, an interpackage connection would be needed. As a result, a considerable amount of space on a circuit board is required to interconnect both the switches and the individually packaged filter devices. Inter-connections between the devices must be provided that may  
15 increase costs as well as parasitic capacitance.

It is also relatively difficult to handle the small dies associated with the radio frequency MEMS switch and the film bulk acoustic resonator. It is relatively awkward to interconnect these dies and the size of resulting  
20 structure may be considerable.

Thus, there is a need for better ways to assemble film bulk acoustic resonators with microelectromechanical system radio frequency switches.

### Brief Description of the Drawings

Figure 1 is an enlarged cross-sectional view of a microelectromechanical system switch in accordance with one embodiment of the present invention;

5        Figure 2 is an enlarged cross-sectional view of a film bulk acoustic resonator in accordance with one embodiment of the present invention;

10       Figure 3 is an enlarged cross-sectional view of a module including the switch of Figure 1 and the film bulk acoustic resonator of Figure 2 in accordance with one embodiment of the present invention;

Figure 4 is an enlarged cross-sectional view of the embodiment shown in Figure 3 after further processing in accordance with one embodiment of the present invention;

15       Figure 5 is a cross-sectional view of the embodiment shown in Figure 3 after further processing in accordance with another embodiment of the present invention; and

20       Figure 6 is an enlarged cross-sectional view of the embodiment shown in Figure 3 after further processing in accordance with yet another embodiment of the present invention.

### Detailed Description

Referring to Figure 1, a microelectromechanical system (MEMS) radio frequency (RF) switch 11 may be formed on a substrate 10. The switch 11 may include a cantilevered switch element 14 that is electrostatically attracted

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towards and away from the substrate 10 to make or break contact with the contact 12. In one embodiment, an electric field may be utilized to attract the cantilevered switch element 14 to make contact with the contact 12.

5 Referring to Figure 2, a film bulk acoustic resonator (FBAR) 15 in accordance with one embodiment of the present invention may be formed on a substrate 16 with a backside cavity 24. An upper electrode 22 and a lower electrode 18 may sandwich a piezoelectric film 20.

10 Referring to Figure 3, the switch 11 may be assembled in an inverted configuration on the film bulk acoustic resonator 15 using a hermetic sealing material 26 and a conductive interconnect 28. The interconnect 28 may make an electrical connection between the upper electrode 22 and  
15 the contact 12a and between the lower electrode 18 and the contact 12b associated with the switch element 14a. In some embodiments, the interconnect 28 material may be a metal bonding material such as a solder joint or a metal thermo-compression bonding, to mention two examples.

20 A chamber 48 may be defined between the switch 11 and the FBAR 15 using the hermetic sealing material 26. The material 26 may be a solder ring, frit glass ring, anodic bonding, or a plastic ring, to mention a few examples. Suitable plastic rings includes those made of epoxy, resin,  
25 or a polymer such as benzocyclobutene (BCB).

As a result, the switch 11 may be packaged in close proximity to the FBAR 15, reducing the interconnection length and simplifying the interconnection process. This may result in better RF performance, fewer components, and  
5 a smaller footprint in some embodiments of the present invention. In addition, the module may have lower costs than separate switch and filter devices. Also, the packaging may be implemented at the wafer level.

Thus, a wafer containing a large number of switches 11  
10 and FBARs 15 may be combined together to define individual modules 50, which are subsequently separated from the wafer, forming, at the same time, a large number of modules 50. In one embodiment of the present invention, one or both of the wafers, including the switches 11 and/or the  
15 FBARs 15, may have the conductive interconnect material 28 formed thereon before combining with the other of the switch or FBAR. The conductive material 28 may be applied using thick resist or electroplating, as two examples. One or both of the wafers may also have the sealing material 26  
20 preapplied. The FBAR 15 and switch 11 may be assembled together, at the wafer level, using an assembly tool such as a wafer bonder. In some embodiments, this assembly may be done in a dry ambient at a specified pressure. The cavity 24 in the backside of the FBAR 15 wafer can be made  
25 either before or after the wafers are assembled into the

module 50. A wafer 30 may be applied over the backside cavity 24 to form the module 50.

Referring to Figures 4 through 6, a variety of techniques may be used to form interconnects from the outside world to the switch 11 and the FBAR 15. Referring to Figure 4, a metal via 32 may be formed through the layer 30 down to the upper electrode 22 and the lower electrode 20 of the FBAR 15 in one embodiment of the present invention.

Alternatively, as shown in Figure 5, metal vias 34 may be formed from the top through the substrate 10 of the switch 11 to make electrical contact with the contacts 12 of the switch 11.

In accordance with still another embodiment of the present invention, electrical interconnections may be made by sawing through the wafer 30 and the wafer including the FBAR 15 to create the tapered shape shown in Figure 6. The FBAR 15 may then be coated with a contact metal 36 that makes electrical connections to the upper and lower electrodes 22 and 18 of the FBAR 15. In some embodiments, the tapered structure may be formed by sawing at the wafer level.

In one embodiment, the FBAR membrane may not be released when the switch 11 and FBAR 15 wafers are bonded together. In this embodiment, the FBAR 15 still needs a backside silicon etch, that may be done either using a wet

etch such as KOH or tetramethylammonium hydroxide (TMAH), or by backside grinding the FBAR wafer and using a plasma etch. The packaging may be completed afterwards by bonding the wafer 30 to the backside of the filter 15 wafer.

5           While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall  
10 within the true spirit and scope of this present invention.

What is claimed is: